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METHOD OF CODING INFORMATION DISTRIBUTED BY WIRELESS COMMUNICATION LINES UNDER CONDITIONS OF INTERFERENCE

The subject matter of the paper is the processes of analysis and evaluation of the effectiveness of information coding methods in wireless systems. The aim is to improve noise immunity of information messages under conditions of powerful electromagnetic interference, with the help of complex signal-code constructions. **The objective** is to develop a method for noise-immune encoding in a wireless information transmission system, providing increase in information transmission rate. The methods used: Simulation and digital signal coding. The following **results** have been obtained: A method for encoding information transmitted via wireless communication lines in presence of interference. For signal coding, it is proposed to use Gaussian monocycle with time-dependent position-pulse modulation (PPM). It is shown that for organization of independent channels within a single frequency band, it is practical to use a system of orthogonal codes. Pulses of the useful information signal accumulated in a receiver correlator provide significantly increase in signal-to-noise ratio, allowing transmission of information over a wide frequency range well below the noise level. As a result of encoding information in wireless information transmission systems with the help of ultra-short pulse signals, the effectiveness of the proposed method is a quantitatively and qualitatively evaluated. **Conclusion.** Using Pulse Position Modulation coding in wireless information transmission systems allows transmitting large volumes of information with high transmission rate and high noise immunity of the communication channel as well as protecting the channel from message interception. Ability to work with low radiating power and high signal capacity to penetrate various obstacles ensure fulfilment of electromagnetic compatibility requirements as well as stable communication in conditions of multipath radio wave propagation. A possibility that powerful electromagnetic disturbances accompanying a lightning discharge may have catastrophic impact on the information transmission channel is also eliminated.

Keywords: wireless communication line; information coding method; time-dependent position-pulse modulation; lightning discharge; electromagnetic compatibility; electromagnetic interference.

Introduction

Ongoing complication of the tasks to be solved in critical systems, for example, in control systems of nuclear power plants or in space rocket complexes, necessitates increase in quantity and variety of computer equipment involved.

The requirements to the reliability of such equipment constantly grow as well. However, an analysis of failures of such systems [1] shows that the number of accidents and the risks associated with them have been steadily increasing recently. This is mainly due to computer software failures. In 10% of cases, rocket and space equipment (RSE) failures occur because of on-board computer software failures [2, 3]. Therefore, software is one of the main sources of errors that lead to emergencies. Software failures caused by distortions of information occurring in inter-unit communication lines exposed to external interference are among the most dangerous. In particular, a powerful electromagnetic field accompanying a lightning is an extremely dangerous source of interference [4]. Such interference is characteristic for wide frequency range (0.3-30 MHz) in combination with the large amplitude of pulsed electromagnetic field (15-100 kV/m). These are extremely dangerous factors, especially for wire communication lines.

Problem analysis and task formulation

Information coding solves two tasks – synchronization and noise immunity improvement. Here noise immunity of an information transmission channel means the maximum level of electromagnetic interference affecting the communication channel, such that the channel retains the required quality of operation [5]. Reed-Solomon codes, as a kind of error correction block codes, have a huge advantage in comparison with binary codes when external impulse noise is considered. However, these codes require dual redundancy and complex modem schemes.

Therefore, the encoding comes at a price of reduction in the useful information transmission rate. At the same time, there is a need for increasing transmission rate between radio system (RS) units in wireless communication channels and it requires using the widest possible frequency range. Therefore, the use of Direct Sequence Spread Spectrum (DSSS) method for widening the spectrum while modulating and demodulating information signals makes it possible to increase interference immunity of a communication channel substituting one bit of original information with N bits of a spreading code combination.

Physical limitations of radio frequency resources enforce stringent requirements as to ensuring electromagnetic compatibility (EMC) of a system. Especially important is to solve this problem for limited and closed spaces, e.g. interior of RSE cases. Thus, to transmit information between RSE blocks, it is necessary to use ultrashort pulse signals with ultra-wide spectrum.

Task solution

An ultrashort pulse is not capable of information transmission. The transmission is possible only with a series of such pulses. A method of information encoding and transmission being proposed here consists in generating a sequence of ultrashort pulses, which provides increasing information transmission rate. Some reference or basic sequence of pulses is used instead of a carrier signal. Pulses of the sequence are generated at strictly defined intervals. Information is encoded with the temporal shift of a pulse with respect to the reference signal. So a 0 bit can correspond to a pulse transmitted earlier than the reference one, while a pulse coming later than the reference one corresponds to a 1 bit (Fig. 1). This is a kind of time-dependent Pulse Position Modulation (PPM) [6, 7].

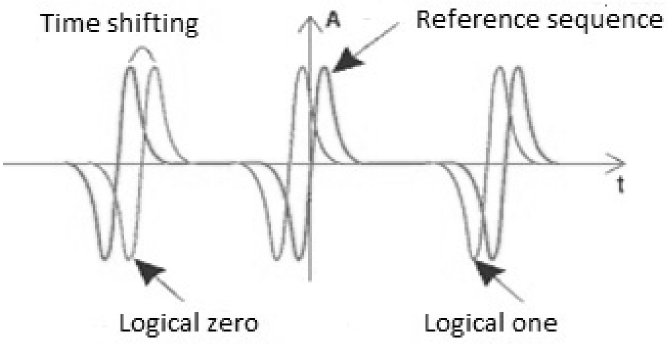

Fig. 1. PPM Modulation

Such coding sequence is based on a pulse signal whose shape is shown in Fig. 2 and is specified with equation (1). With a pulse front duration of 0.5 ns, its spectral range is 2 GHz:

$$A(t) = A_0 \cdot \sqrt{2\pi} \cdot \frac{t}{\Delta t} \cdot \exp\left(t^2 / \Delta t^2\right), \quad (1)$$

where Δt is pulse duration; t is time and A_0 is pulse amplitude.

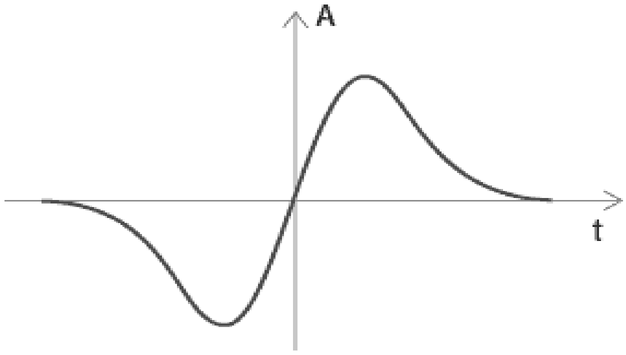

Fig. 2. The shape of an ultrashort pulse

Thus, the implementation of ultra-wideband (UWB) technology enables significant increase in data transfer rate up to 400-500 Mbit/s.

Inter-unit conductor communication lines of the system, e.g. cable lines or twisted pairs do not have sufficiently broad bands. Wireless links should be used for such broadband signals. Since the signal spectrum is broadband, it is necessary to provide for the possibility of frequency range sharing, i.e. multiple access.

At the same time, using many sources of broadband electromagnetic radiation in a closed confined space creates a complex electromagnetic environment (CEE) inside the object, putting forward higher requirements to noise immunity of circulating information. Reducing the radiation level of the broadband signal transmitters below the noise level makes it possible to meet the requirements of EMC, and this leads to improvement of noise immunity.

To separate several information communication channels, each of them is assigned its own spreading code combination. This is a pseudo-random sequence, whose elements constitute an orthogonal basis; this sequence specifies the channel code. And the information message is decoded only if the receiver and the transmitter share the same channel code, which improves interference immunity of the information circulating in the system.

Extraction of a useful signal in presence of noise is performed through correlating received and reference signals. A correlator performs convolution of the received signal and the reference signal. The correlator is an ideal detector for determining time shifts of the received pulses relative to the reference ones. When a 1 bit is received, the value of correlation function is equal to + 1, while its value is - 1 on reception of a 0 bit. In all other cases, the value of the correlation function is 0. Since a bit of information is represented e.g. with 200 ultrashort pulses and on codes coincidence the bits are accumulated in the receiver's integrator, a bit will be detected correctly even if 99 pulses out of 200 are corrupt.

A useful signal is extracted from the noise level and it exceeds the noise significantly: Signal-to-noise ratio here constitutes 23 dB. It should be noted that encoding an information bit with a series of ultrashort pulses eliminates the multipath signal propagation problem.

This is because any reflected signal received with an invalid time shift resulted from a different propagation path is discarded as an interference signal. At the same time, using a series of ultrashort pulses to encode an information bit makes it possible to eliminate inter-symbol interference because the energy of the preceding pulse completely dissipates before the following ultrashort pulse from the coding series is received.

A comparative analysis of noise-proof codes currently in use is shown in Figure 3. The analysis revealed that the duration of one information bit is within 1 to 4 seconds.

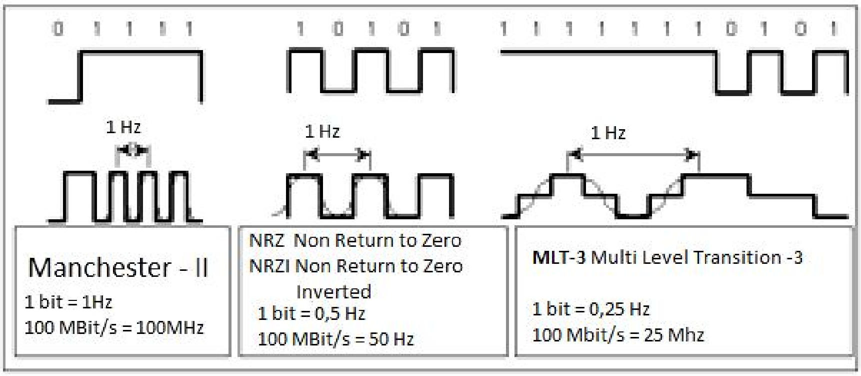

Fig. 3. Dependence of a carrier frequency on the encoding method

One Hertz of a carrier transmits one bit with Manchester code, two bits – with NRZ code and four bits – with MLT-3 (Multi Level Transmission-3).

Calculation of external interference impact on signal transmission and development of methods for reducing this impact are the main issues solved within the Theory of Noise Immunity. The most dangerous external interference affecting noise immunity of information circulating in a system is an electromagnetic field accompanying a lightning discharge with duration of 0.2 ms [4]. Such field always destroys an information bit encoded with any of the currently used noise-immune encoding methods. But with PPM encoding method, an external electromagnetic field accompanying a lightning bolt does not cause complete destruction of an information bit due to its representation, e.g. by 200 ultrashort pulses. The field can only reduce the signal-to-interference ratio at the receiver by 20%. In such case, the signal-to-noise ratio is decreased by 1 dB from 23 dB to 22 dB, and this would not cause an information signal failure.

Conclusions

Thus, application of PPM coding to information transfer in a confined space allows interference-free wireless information exchange in such conditions. This makes it possible to remove wired inter-block information communication lines, significantly reducing the weight of an RSE object. At the same time, due to the organization of ultra-wideband wireless communication, the information exchange rate between units of the system increases significantly. The catastrophic effect on information transfer channels resulted from powerful electromagnetic fields accompanying a lightning bolt can be eliminated as well.

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Метод кодування інформації,
що розповсюджується по безпроводовим лініям зв’язку в умовах завад

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Предметом вивчення є процеси аналізу та оцінки ефективності методів кодування інформації в безпроводових системах. **Мета** – підвищення завадостійкості інформаційних повідомлень в умовах дії потужних електромагнітних завад шляхом застосування складних сигнально-кодових конструкцій. **Завдання:** формування методу завадостійкого кодування у безпроводовій системі передачі інформації, яка дозволяє підвищити обсяг та швидкість передачі інформації. Використовуваними **методами** є: методи імітаційного моделювання та цифрового кодування сигналів. Отримані такі **результати**. Запропоновано метод кодування інформації яка розповсюджується по безпроводовим лініям зв'язку в умовах завад. Обгрунтовано використання у якості кодового сигналу гаусівського моноциклу із кодуванням інформації за допомогою часової позиційно-імпульсної модуляції. Показано, що для організації незалежних каналів в одній смузі частот доцільно використовувати систему ортогональних кодів. Накопичені у кореляторі приймача імпульси корисного інформаційного сигналу дають можливість суттєво підвищити співвідношення сигнал / шум, забезпечуючи цим можливість передачі інформації у широкому частотному діапазоні значно нижче рівня шуму. В результаті кодування інформації надкороткими імпульсами у безпроводових системах передачі інформації проведена кількісна та якісна оцінка ефективності запропонованого методу. **Висновки.** Використання PPM – кодування у безпроводових системах передачі інформації дозволяє забезпечити великі обсяги та швидкості передачі інформації з одночасною високою завадозахищеністю каналу зв'язку та захистом його від перехоплення. Можливість працювати із малою потужністю випромінювання та висока проникливість сигналів крізь будь-які перешкоди дозволяють виконати вимоги електромагнітної сумісності та забезпечити стійкий зв'язок в умовах багатопроміневого розповсюдження радіохвиль. При цьому усувається можливість катастрофічної дії на канали передачі інформації потужних електромагнітних завад, які сіпроводжують розряд блискавки.

Ключові слова: шумоподібний сигнал; безпроводова система передачі інформації; часова позиційно-імпульсна модуляція; ортогональне кодування; електромагнітна сумісність.

Метод кодирования информации,
распространяющейся по беспроводным линиям связи в условиях помех

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Предметом изучения являются процессы анализа и оценки эффективности методов кодирования информации в беспроводных системах. **Цель** – повышение помехоустойчивости информационных сообщений в условиях действия мощных электромагнитных помех путем применения сложных сигнально-кодовых конструкций. **Задача**: формирование метода помехоустойчивого кодирования в беспроводной системе передачи информации, позволяющего повысить объем и скорость передачи информации. Используемыми **методами** являются**:** методы имитационного моделирования и цифрового кодирования сигналов. Получены следующие **результаты.** Предложен метод кодирования информации, распространяющейся по беспроводным линиями связи в условиях помех. Обосновано использование в качестве кодового сигнала гауссовского моноцикла с кодированием информации посредством временной позиционно-импульсной модуляции. Показано, что для организации независимых каналов в одной полосе частот целесообразно применять систему ортогональных кодов. Накопленные в корреляторе приемника импульсы полезного информационного сигнала дают возможность существенно повысить соотношение сигнал/шум, обеспечивая возможность передачи информации в широком частотном диапазоне значительно ниже уровня шума. В результате кодирования информации сверхкороткими импульсными сигналами в беспроводных системах передачи информации проведена количественная и качественная оценка эффективности предлагаемого метода. **Выводы.** Использование PPM – кодирования в беспроводных системах передачи информации позволяет обеспечить большие объемы и скорости передачи информации при высокой помехозащищенности канала связи и защиты его от перехвата. Возможность работы с малой излучаемой мощностью и высокая проникающая способность сигналов через различные препятствия позволяют выполнить требования по электромагнитной совместимости и обеспечить устойчивую связь в условиях многолучевого распространения радиоволн. При этом устраняется возможность катастрофического воздействия на каналы передачи информации мощных электромагнитных помех, сопровождающих разряд молнии.

Ключевые слова: шумоподобный сигнал; беспроводная система передачи информации; временная позиционно-импульсная модуляция; ортогональное кодирование; электромагнитная совместимость.